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Thomas

Westmorland Slates

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Westmorland Slates

Their Geology, Chemistry, and Architectural Value

A PAPER READ BEFORE
THE MANCHESTER SOCIETY OF ARCHITECTS
7TH JANUARY 1896

BY

J. J. THOMAS, M.I.M.E. (Kendal)

Member of the Institute of Mining and Mechanical Engineers, Newcastle
Member of the Mining Association and Institute of Cornwall;
Manager of Jas. Stephenson & Co.'s Tilberthwaite
Green Slate Quarries

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WESTMORLAND SLATES:

THEIR GEOLOGY, CHEMISTRY, AND ARCHITECTURAL VALUE.

By J. J. THOMAS, KENDAL.

Read before the Manchester Society of Architects, 7th January 1896.

So far as I am aware, it is seldom that slates and slate-quarrying form the subject of a Paper to be read before an Architectural Society, and I wish to say at the outset that the opportunity now afforded of placing on the records of this important Society some account—imperfect though it be—of Westmorland slates is one which I highly appreciate.

It will be generally admitted, I believe, that slates deserve to be classed among the most important materials with which the architect, during the course of his professional career, has to deal; but it is doubtful whether the same scientific study has been made of them as of many other articles used in architectural work. It may be interesting at this point to give some idea of the magnitude of the industry which we have under consideration, and the quantity of slates produced in this country. I find from official statistics that about 15,000 men are employed in the slate quarries of Great Britain and Ireland; and that they produced, in 1894, 461,673 tons of slates, amounting in value to £1,171,366; out of this total £940,553 worth were used in this country, the remainder being exported to various foreign countries, a list of which, with the quantities sent to each and their values, I append to this Paper. It is also interesting to note that the slate trade comes fourth on the list of those industries tabulated in the mineral statistics of Great Britain and Ireland. Coal comes first,

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the value in 1894 being £62,730,179; stone, £7,695,716; iron ore, £3,190,647; slates, £1,171,366.

From the foregoing figures it will be seen that the slate industry in this country is one of very considerable magnitude, and represents in money value a large annual turnover.

In order to make the Paper easy to follow and as intelligible as possible, I propose to deal with the subject under three main headings:—

1. The Geological Position and Extent of the Slate-producing Area of the Lake District.

2. The Chemical Composition of Slates, and the Action upon them of Impure Atmospheres and varying Degrees of Temperature.

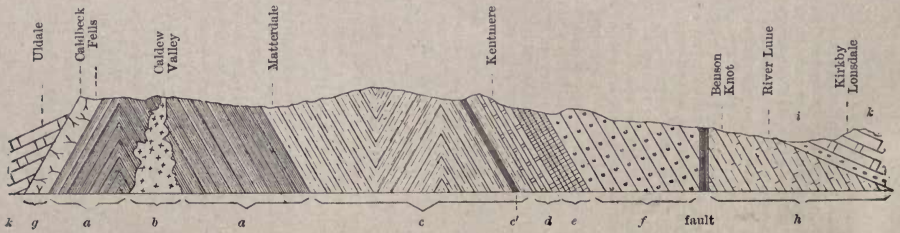
3. General Description of Westmorland Slate-Quarrying, the Method of preparing the Slates, Cleavage, Architectural Value.

The Geological Position and Extent of the Slate-Producing Area of the Lake District.—The Lake District proper is composed of Silurian strata, both the lower and upper divisions of the formation being represented, and they may be divided into five groups, which I give in order of deposition, viz.:—

Skiddaw Slates, 7,000 feet Green Slate and Porphyry Series, 7 to 10,000 feet Coniston Limestone, 300 feet	Lower Silurian.
Coniston Flags and Grits, 7,000 feet. Ludlow Rocks, 5,200 feet.	Upper Silurian.

From the above table it will be seen that the Skiddaw Slates, which comprise a group of rocks of enormous thickness, and cover an area of about 200 square miles, form the base of the Lower Silurian series of the Lake District, and have their equivalent in the Arenig Slates or Lower Llandeilo Flags of North and South Wales.

The group mainly consists of dark slates or slaty mudstones, with occasional beds of harder material of a flaggy nature, but almost devoid of cleavage. Some geologists describe the Skiddaw Slates as of little industrial importance: so far as slates are concerned, this may be correct, as, with the exception of Bowscale Fell and Embleton Valley Slate Quarries, both of which, I believe, are now idle, no roofing slates are obtained from this group. But several important, and at one time lucrative, mineral deposits were worked in this formation, among which may be mentioned the famous Goldscope Mine, which produced in former years both gold and copper, the latter, it is said, in large quantities. A number of other mines produced lead, copper, iron, and cobalt. It may also be stated that



a, Skiddaw Slates.
b, Granite of the Caldew Valley.
c, Green Slates and Porphyries.
c', Fossiliferous Band near top of *c*.

d, Coniston Limestone.
e, Coniston Flags.
f, Coniston Grits.
g, Felspathic Traps (G. S. and P. Age).

h, Ludlow Rocks.
i, Upper Old Red Sandstone.
k, Carboniferous Rocks.

[*From Nicholson's "Geology."*]

good flags have been quarried at Crummock, and near Shap slate pencils were once largely produced.

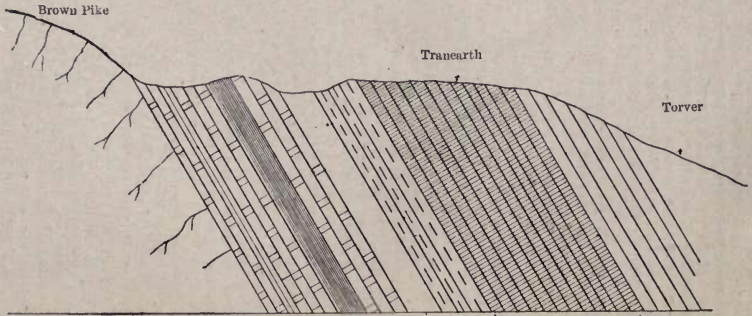
Lying conformably on the Skiddaw Slates are the Green Slate and Porphyry series, also of Lower Silurian age, their equivalent in the Silurian Rocks of North and South Wales being part of the Bala Beds, the whole of Llandeilo, and probably part of the Arenig formation.

It need hardly be mentioned that this group of rocks is one presenting many points of considerable interest, and has for years attracted the attention of some of our leading men of science, several of whom have placed on record, at considerable length, the result of their investigations; and, although it would be extremely interesting to follow some of these geological pioneers in the study of these rocks, I shall only briefly notify their chief geological features, and proceed more especially to deal with them as slate-producing rocks, as it is from this formation that all the Westmorland green roofing slates of commerce are obtained.

The group is one of great superficial extent, extends twenty-five miles in an E.N.E. and W.S.W. direction, and averages about thirteen miles in a N.W.W. and S.S.E. direction; covers an area of about 325 square miles, and attains a thickness of about 10,000 feet. It is composed of a vast accumulation of bedded felspathic ashes and breccia, with alternate beds of porphyries of considerable thickness. The whole group, which is entirely devoid of fossils, except a small band near the top, is the result of a series of volcanic actions, estimated to have spread over a period of about one and a half million years. The chief centres of this volcanic activity are supposed to have been Ambleside and Keswick, in addition to which there were several other smaller centres of irruption in various parts of the district.

The volcanic activity which commenced at the close of the Skiddaw Slate period is not supposed to have been marked in its earlier stages by any general upheaval of rocks. In all probability the earlier volcanic outbursts were submarine, as the rocks at Eycott Hill, near Black Coombe, and also in an exposure near Shap, seem to point to the conclusion that the lower deposits, although in all probability thrown high above the water, fell back and were interstratified with deposits of mud and sand. Later in the period, however, it seems clear that the volcanic action was accompanied by a gradual upheaval of the old ocean bed.

Turning now to the series, and examining it from a quarrying and slate-producing point of view, I think it may be safely stated that it presents more difficulties and complications than any other slate-producing formation



1, Green Slates and Porphyries.
2, Coniston Limestone and associated shales.
3, Gray Grits.
4, Coniston Flags.
5, "Sheerbate" Flags.
a, Probable position of black Graptolite shales.

[*From Nicholson's "Geology."*

on the geological chart. Out of the whole 325 square miles which this group covers, there are only about twelve or fourteen beds from which slates are obtained. Ten or twelve of these are situate near the top of the series in the Coniston district, and the remainder at the base of the series in the neighbourhood of Keswick. The whole area between these two points is practically barren of any rock sufficiently well cleaved to produce roofing slates.

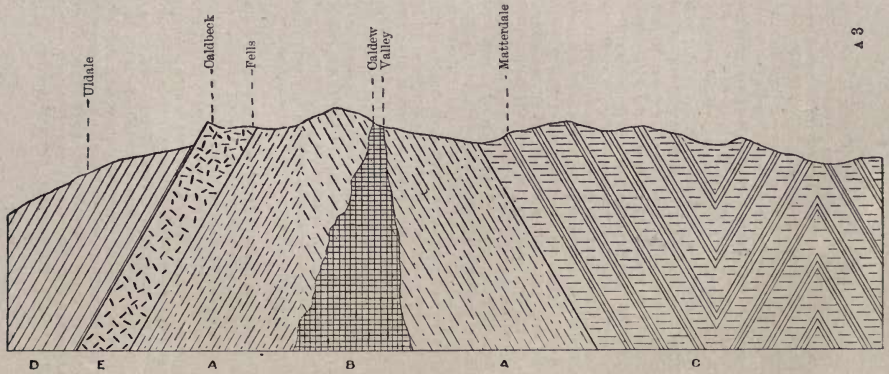
It may be pointed out here that the fine ash beds from which the slates are obtained are in each case in close proximity to where the main centres of eruptions are supposed to have been located, and this may point to a period of less violent volcanic activity than when the porphyries and breccias were emitted.

Accompanying the fine ash beds are almost invariably found beds of breccia, also cleaved, but generally too rough and coarse in the grain to make marketable roofing slates. One of the principal difficulties to contend with in this series is the uncertainty of the continuity of the bed of slate, from the fact that there is a marked difference between a volcanic deposit and a sedimentary formation. The former is not only subject to considerable variation in the character as well as in the degree of fineness of its deposit, but also in its extent; while, on the other hand, sedimentary formations, such as occur in North Wales, have been formed under deep sea, and during a period of comparative calmness. You will therefore readily understand why a sedimentary bed is much more regular than a fine ash bed emitted from the crater of a volcano.

Coniston Limestone.—The Green Slate and Porphyry series is overlaid by the Coniston Limestone, a narrow band averaging about 300 feet in thickness, and extending from Millom to Wasdale Crag, near Shap. This is considered to be the equivalent of the Bala Limestone of North Wales, and is the topmost bed of the lower Silurian Rocks of the Lake district. It consists of hard and compact limestone of a dark blue colour, and is largely intermixed with cleaved slates. It is of little or no commercial value.

The Limestone is succeeded by the *Stockdale Shales*, a narrow group of Graptolitic mudstones, with bands of dark and purple shales, forming the base of the Upper Silurian of the district. On Torver and Broughton Moors several attempts have been made at quarrying these shales for slates and flags, but hitherto the discoveries have not been of an encouraging character.

Lying on the Stockdale Shales are the *Coniston Flags and Grits*, which are precisely the same as the Denbigh-



A, Skiddaw Slates.
B, Granite of the Caldew Valley.
C, Green Slates and Porphyries.

D, Carboniferous Rocks.
E, Felspathic Traps of the Caldbeck Fells, the equivalent of the Green Slates and Porphyries.

[*From Nicholson's "Geology."*

shire Grits and Flags overlying the Tarranon Shale in North Wales. The lower bed—the flags—attains a thickness of about 2,800 feet, while the grits measure 4,000 feet in thickness. The flags consist of dark blue sandy mudstones, which when cleaved are largely quarried for slates and flags, the principal quarries in this series being on Torver and Kirkby Moors. The grits are composed of harder material, principally gritty sandstones with interstratified beds of slates and flags. These bring us to the *Ludlow Rocks*, an extensive group of fossiliferous rocks extending from Kendal to the Lune Valley, and, as will be seen from the section, are of the same geological age as the formation bearing the same name in North Wales.

The above brief outline of the geology of the slate formations brings us to the next heading—viz.:—

The Chemical Composition of Slates, and the Action upon them of Impure Atmospheres and varying Degrees of Temperature.—However interesting and valuable may be the inquiry into the geological history and relative age of the various slate-producing rocks, and the manner in which they have been formed, it is possible that from a utilitarian point of view the chemical analysis of the slates, and the effect varying degrees of temperature, &c., have upon them, is equally, if not more, important to us.

There is probably no article of domestic use with which we are more familiar and have more prominently brought before us than a slate; even from our earliest schooldays we were brought face to face with this useful article of commerce. It is, however, doubtful whether many, even of those who most frequently use them, have thought it necessary and of sufficient importance to inquire into the characteristics and relative values of the different kinds of slates.

It is a remarkable fact that although, as will be readily admitted, there is a great difference in the "wearing" quality of the various descriptions of slates, the variation in the chemical compositions is exceedingly slight. I will give the analyses of some of the principal varieties of roofing slates.

1. *Analysis of ordinary blue Welsh roofing slate, Cambrian formation; by Professsor Hull.*

Silica	60·50
Alumina	19·70
Iron (protoxide)	7·83
Lime	1·12

Magnesia	2·20
Potash	3·18
Soda	2·20
Water	3·30
	100·03

2. *Analysis of a dark-blue slate from Llangynog, North Wales; by D. H. Richards.*

Silurian Rock. Slate dried at 100° C.

Loss on ignition	3·720
Silica	60·150
Alumina	24·200
Protoxide of Iron	5·837
Sesquioxide of Iron	1·815
Not determined (alkalies)	4·278
	100·00

3. *Analysis of the material of the green bands in the bluish-purple slates at Llanberis; made by the Royal School of Mines. Cambrian formation.*

Silica	66·45
Titanic Acid	0·63
Alumina	13·38
Protoxide of Iron	1·71
Peroxide of Iron	1·41
Protosesquioxide of Manganese	0·91
Lime	2·86
Magnesia	6·28
Potash	0·05
Soda	0·90
Carbonic Acid	1·30
Combined Water	3·90
Hygroscopic Water	0·13
	99·91

4. *Analysis of the purple slates of Nantlle.—Kirwan's Mineralogy. Cambrian formation.*

Silica	48
Argillaceous Matter	26
Magnesia	8
Lime	4
Iron	14
	100

5. *Analysis of a green Westmorland slate; by George Vogt.*

Silica	50·88
Alumina	14·12
Iron Oxide (Ferrous)	9·96
Lime	8·72
Magnesia	8·67
Carbon Dioxide	6·47
Potash	·88
	99·70

It will be seen from the foregoing analyses that slates are chiefly made up of silica and alumina, from which we may reasonably infer that they were once ordinary clay.

The principal difference in the composition of the Welsh blue, Welsh purple, and Westmorland green, lies in the varying proportions of iron which they contain. The blue Welsh slate contained 7·83 per cent. of iron in the ferrous state FeO; the purple contained 14 per cent. of iron in the ferric state Fe_2O_3; and the green Westmorland slate contained 9·96 per cent. of iron in the ferrous state.

It is generally asserted that iron is the agent which determines the colour of the slate, and it has always been laid down that Westmorland slates derive their colour from the presence of iron in the ferrous state, while the purple slates of North Wales derive their colour, like the marls of the Permian Rocks, from iron in the ferric state; but on examination of the analyses given it will be seen that the iron in the blue Welsh slate is also in the ferrous state, hence it is difficult to determine with any degree of certainty which of the elements plays the most important part in the determination of colour.

One of the most important points to notice in the determination of the quality of a slate is its porousness, as undoubtedly those slates, other circumstances being equal, are best which absorb the least amount of moisture, for the absorbed moisture not only increases the weight of the slate, but in frosty weather is converted into ice, and swells, with consequences highly detrimental to the soundness of the slate.

Several experiments have from time to time been made to demonstrate this quality. I will only mention two, which I have made specially for this Paper.

I took three slates, each having a surface of 144 square inches. I had them all carefully weighed, and then placed in a bath of water. One was taken out after an immersion of fifty hours, and after the surface-water had ceased to drip, was weighed again, and I found the weight

100 grains in excess of its original weight. It was then placed before a fire, and in a few minutes the surface was quite dry, and on being put on the scales again was only 30 grains in excess of its original weight. The other two slates were in the water 312 hours, and after the surface-water had ceased to drip I placed them on the scale. In the one case the increase in weight was 127 grains, and in the other 200 grains. Both were then placed before a fire, and, as in the first case, the surface was perfectly dry in a few minutes, and on being again weighed one was 8 grains heavier than its original weight, while the other was exactly its original weight. This shows in one case the absence of any absorption, and in the others only a few grains, which may be considered as highly satisfactory.

It may be taken that the amount of moisture the best Westmorland and Welsh slates may absorb is not sufficiently great to make any material difference in their weight, or in the action of frost upon the absorbed moisture; but there are slates to which, from their flaky and jointy nature, the absorption of moisture is highly detrimental, as the absorbed water when frozen tends to loosen the joints and open the flakes, which process, when frequently repeated, materially damages such slates. These, however, when used in countries less liable to sudden and violent changes in temperature than we are in England, prove as serviceable as the best known slates in this country. There is still another point of importance depending upon the compactness or otherwise of the slate. It was shown by the tables of analyses that all slates contain varying percentages of iron, some in the ferrous and some in the ferric state. Iron, as you all know, has a great affinity for oxygen, and if the slate be porous the oxygen of the air combines with the iron when in the ferrous state, changing it into ferric, with the result that the colour is altered and decomposition on a small scale is carried on.

In addition to this there is a further chemical action that takes place, and a much more disastrous one than the changing of ferrous into ferric oxide. As the analyses show, all the slates contain calcic carbonate, and some of them magnesic carbonate. If the slate be sufficiently porous to admit carbon dioxide (Co_2), which is equally prevalent in otherwise pure and impure atmospheres, the carbonates are changed into bi-carbonates, which are soluble in water—$CaCo_3 + H_2Co_3 = CaH_2(CO_3)_2$—the natural result of this being that the slate will in time decompose, and its "waterproof" quality be eventually destroyed.

Some time ago a Swiss scientist contributed a Paper on

Slates to one of the magazines, in the course of which he suggested the following experiment to test the quality of a slate:—Reduce the slate to powder, add hydrochloric acid; if strong effervescence, proof of a bad slate, full of lime. A portion of another slate is taken, and likewise reduced to powder, and placed in a test tube and heated over a Bunsen flame. A yellow sublimate and fumes of sulphurous acids prove the presence of much iron pyrites, consequently a bad slate.

I am afraid I cannot agree with these conclusions, as my experience, and that of many others, of slates containing both lime and iron pyrites proves the contrary.

The analyses I have given show the presence of lime in all the slates which, on the application of HCL., gives a brisk effervescence, and if the above contention be correct, we must classify all these as bad slates, whereas quite the contrary is the fact.

The best Westmorland slates which we know have stood the action of the atmosphere in some instances at least 100 years; and of some of them it would be safe to state that they have been exposed 200 years, and still show no signs of decay. The same might be said of some slates containing iron pyrites, which would give chemical results pointing, according to this theory, to a bad slate; but here, again, we are in a position to produce slates heavily charged or permeated with iron pyrites—such, for instance, as the Ballachulish and Easdale slates, in the North of Scotland, both of which have stood for a considerable time, without the least sign of decay from this cause.

After all, I am much inclined to believe that there is a limit to chemical analysis in the determination of the quality of a slate. The chemical composition of most slates with which we have to deal is very much the same, but we do know that the wearing quality of the various slates differs materially. All this seems to me to suggest the presence of another agent playing an important part in the formation of a slate, and I humbly submit that the *mechanical arrangement* of the particles contained in the slate has more to do with the determination of quality than the best conceived proportions in chemical analysis.

If we were to take the various elements or ingredients which from analysis we know constitute the best slate, mix all together, and apply sufficient pressure to produce a compact sheet or block, we should not produce an article possessing the same qualities as an ordinary roofing slate.

In support of this theory, I beg to mention as an illustration the substances known as diamond and graphite,

both of exactly the same chemical composition but differing widely in their properties and ultimate value, which seems to me to point to a different mechanical arrangement of the particles of which the two substances are composed.

How, then, are we to determine the quality of a slate? For my part, while acknowledging with gratitude the assistance obtained from the chemical laboratory, I am of opinion that the best and safest of all tests is that of experience. We know from evidence furnished us by buildings erected 80, 100, and even 150 years ago that certain materials have stood the most severe of all tests, that of time; and until chemical science has discovered a more reliable one, we must give time and experience the pre-eminence.

Amongst those materials I may safely state that none are more conspicuous and none have more highly distinguished themselves in the war with the elements than Westmorland green slates.

General Description of Westmorland Slate Quarries; the Method of Preparing the Slates. Cleavage. Architectural value. – The question of cleavage is perhaps one in which the quarry owner is more directly interested than the architect, but a Paper on slates would be far from complete if no reference were made to this subject, and on this ground I crave your indulgence while notifying some of the principal points coming within our scope under this heading.

While scientists are mainly interested in discovering the agent or agencies by which cleavage was produced, the quarry owner, on the other hand, is more especially concerned in the character of the cleavage in the particular bed of slate he is working, as on the nature of the cleavage depends to a large extent the value of his bed of rock. This property of slate rock by which we are enabled to split it into thin pieces consists of lines or lamination planes running in the direction of the strike of the bed, and always at right angles to the dip of the rock, but cleavage lines occur at varying angles of inclination from the planes of bedding. In Westmorland the cleavage lines are not so well developed as in the slate rocks of North Wales, where it is possible to split a block $2\frac{1}{2}$ inches thick into 40 slates equal to $\frac{1}{16}$ of an inch each in thickness. It would, however, be well-nigh impossible to get from any Westmorland rock an equal number of slates from a block of the same thickness.

As to the manner in which slaty cleavage was produced, I will merely mention that there are two theories – the magnetic and mechanical.

The former was held by, amongst others, Professor

Sedgwick, in support of which it is pointed out that the direction of the cleavage being N.N.E., coincides with the course taken by the magnetic currents which are passing through the earth.

On the other hand, it is assumed by a number of eminent scientists that cleavage is due to mechanical forces that compressed the sediment at right angles to the line of cleavage. Dr. Sorby, who studied and examined it microscopically and otherwise, states that the "sedi-"ment has been compressed to about one-half of its origi-"nal bulk, and the particles pressed with their flattest "sides towards each other." This arrangement may be seen by grinding a piece of slate thin enough to admit light through it, the particles may be then discerned by the aid of a pocket lens, or to better advantage if placed under a microscope. The specific gravity of Westmorland slates is as follows:—

Green, 2·77. Blue, 2·73.

If all the slates were split to equal thickness, the difference in weight on roof timbers would be very small, whichever kind of slate was used.

The late Bishop Watson gives in his Chemical Essays the result of a series of tests made to determine the weight of a cubic foot of slate, and he found that the difference between a cubic foot of the heaviest and a cubic foot of the lightest of 14 different sorts was only 65 oz., or about $\frac{1}{43}$ part of the weight of the heaviest sort. The following is a list of the tests:—

	Ounces.
Purple Slate. Kentmere, near Kendal . .	2797
Pale Blue. Coniston, Waterhead . . .	2791
Dark Blue. Troutbeck	2781
Pale Blue. Thrang Crag	2780
Pale Blue. White Moss	2779
Deep Blue. Old Cauldron	2778
Pale Blue Greenish. Near Ambleside . .	2768
Pale Blue. Ingleton, Yorkshire . . .	2767
Dark Writing Slate. Bannisdale . . .	2765
Blackish. Head of Windermere . . .	2758
Deep Blue. Langdale	2752
Greenish Blue. Kentmere	2750
Blackish. Cartmell, Lancashire . . .	2740
Very Pale Blue (fine grained.) Ambleside .	2732
Medium weight of cubic foot . . .	2767

It is possible that there may be some present who have not had an opportunity of visiting a slate quarry, and witnessing the process of slate-making, and perhaps

a few descriptive remarks will therefore not be out of place.

Slate quarries may be divided into two classes, open top and underground. The former, when situate on the hill-side, are generally worked by means of adit levels, through which the slate material and débris are carried out; but when in the bottom of the valleys are worked "pit" like, and the material for slate working, débris, as well as the water, are hoisted to the surface by means of steam engines or hydraulic machinery.

As to the best and most economical of these two methods to adopt, much depends on the nature of the rock, and the amount of "top rock" overlying the slate. If the slate rock be capped with a great thickness of "top rock," it will as a rule be cheaper to work the quarry underground, as the cost of removing this would be so great as often to render the working unprofitable. On the other hand, by working the quarry "close head," or underground, the removal of the "top rock" is dispensed with, but a much larger percentage of the good slate rock is spoiled than in the open quarries, and the work of rendering the roof safe is often very costly.

These are some of the considerations which frequently tax the best energies and resources of the management.

When commencing slate-making it is necessary in the first place to blast the rock from the cliff-side: this is done by means of a hole varying from $\frac{5}{8}$ to $1\frac{1}{2}$ inch in diameter, according to the size of the piece to be dislocated. The depth of the hole depends on the distance the first joint or "back" may be from the face. The hole being bored, a charge of gunpowder is put in, which is fired by means of a fuse or short straw filled with small gunpowder, having fixed to the end a piece of "match paper."

The "docker-up" now proceeds to view the dislocated rock, and by means of a hammer and chisel reduces the blocks into smaller and more convenient pieces. They are now loaded into waggons, and either taken out through the tunnels, or hoisted to the surface by the aid of machinery, and delivered in front of the splitting sheds, their final destination prior to being made into roofing slates.

There is a considerable variation in the size of the blocks, and good judgment, only acquired by experience, is necessary to cut them, so as to avoid waste and to the best advantage. Thus a block 6 feet long × 2 feet wide is cut into two pieces of three feet long each; this is done by cutting a small aperture on one side and applying a series of heavy blows with a wooden mallet on the other side

immediately above the aperture; by this means the block is cut in two. It is now ready for the splitter.

There are two methods of splitting in Westmorland, viz. chisel riving and hammer riving, the latter is peculiarly characteristic of Westmorland—the chisel riving alone being in use in Wales. The chisel-river does his work seated with crossed legs, always putting the left leg over the right; any departure from this is considered slovenly and bad form. He now takes a block, and, resting it on his left knee, proceeds to reduce it to thin slates by the aid of mallet and chisel. The hammer-river, unlike his colleague, works standing. A raised platform or bench is provided on which the block is placed, held by his left hand, while, with the hammer in the right hand, he applies a series of gentle blows along the cleavage planes, with the result that the block is reduced into thin slates. This latter method is much more tedious, and on the whole less expeditious than the former, in addition to which it takes much longer time to become a good hammer-river than a chisel-river.

I may just mention in passing that at Collyweston, in Northamptonshire, slates are produced which are prepared in a somewhat novel manner. The blocks, which are usually quarried in the autumn, are placed in a position in which the moisture will most readily percolate into the natural joints. The moisture freezes, and the blocks split of themselves into slates suitable for roofing purposes.

As to the antiquity of the slate industry in Westmorland, it is difficult to find any reliable data; but it will be perfectly safe to say that quarrying in a crude manner has been carried out for centuries. It is interesting to find, however, that about 100 years ago slates were sent from a Westmorland quarry for Montague House, Whitehall, the Duke of Buccleuch's London residence, from which we may reasonably infer that quarrying had then attained some proportion, and was being carried on more or less systematically; and it may be mentioned here that when this same house was rebuilt about forty years ago the same slates were used over again, and it was found that they worked out so well that new ones were only sent for the additional area to the roof.

Up to within about thirty years ago the method of quarrying was, however, still rather primitive, and the quantities produced on a limited scale. This was in a large measure due to the difficulties of transit, want of enterprise on the part of the owners, and what was perhaps worse than all, the reluctance of both masters and men to

adopt the most improved and expeditious methods of producing. In consequence of this indifference the industry was at one time in great danger of becoming a thing of the past. However, during the last twenty years a remarkable change has been effected in the Westmorland slate trade. The facilities for transit are greatly improved. More energy has been displayed, and more scientific knowledge has been brought to bear upon the working. The newest and most improved methods of production are now employed, with the result that more quarries are in operation, more men engaged, and larger quantities by more than double are produced at this moment, than at any other period in the history of the industry. The outlook for the future is encouraging, the quarries are being deepened, and with increased depth there is always improved quality. The production in the area under our consideration has increased, according to the figures given in the mineral statistics, from 5,309 tons in 1886 to 17,291 tons in 1894. These figures speak for themselves, and point to the growing popularity of these slates amongst architects, and also to unmistakable activity in the slate trade of the northern counties. From an architectural point of view, Westmorland Green Slates are exceedingly valuable. There are no slates with which the architect has to deal that will give more satisfaction and produce better effect than these. They possess all the necessary qualities of a good slate; they are hard—and all good slates are hard, although it must not be taken that all hard slates are good. When struck they will give a clear, ringing sound like a solid piece of metal, whilst the sound from an inferior slate is always dull and thick. Their colour is the most beautiful of all, and, especially when used in combination with any building material of a red or terra-cotta shade, produce a most charming effect. Their lasting quality is proverbial; once a roof is properly covered with Westmorland Green Slates, it is seldom, if ever, any repairs are needed; and when the building has, owing to age or other circumstances, to come down, the slates are as sound as ever, and with a little dressing may be used over again. Their strength and resisting power are very great; it takes on an average 20,000 lb. weight to crush one cubic inch. This quality, in conjunction with their tenacity and elasticity, enables even thin slates to sustain great weight, and gives to them a pre-eminent commercial value for roofing purposes.

In addition to making good slates, the rock is also capable of being worked for other architectural purposes, in the shape of building and monumental stones of almost every description.

Table of Strata.

		Welsh equivalents.
Ludlow Rocks	=	Upper Ludlow. Aymestry Limestone. Lower Ludlow. Upper Wenlock.
Coniston Flags and Grits	=	Denbighshire Grits. Lower Wenlock.
Coniston Limestone	=	Bala Limestone.
Green Slate and Porphyry Series	=	Part of Bala, whole of Llandilo, and perhaps part of the Arenig Formation.
Skiddaw Slates	=	Arenig, with perhaps Tremadoc and Lingula Flags.

Total production of the different Counties in England, Scotland, and Wales during the year 1894.

	Quantities in Tons.	Value at Mines or Quarries. £.
ENGLAND AND WALES—		
Breconshire	—	—
Carnarvonshire	267,083	573,367
Cardiganshire	241	447
Cornwall Devonshire	12,095	23,565
Cumberland	2,786	5,512
Denbighshire	1,524	4,485
Lancashire Westmorland	14,505	40,507
Leicestershire	10	20
Merionethshire	157,816	509,616
Montgomeryshire	3,257	8,229
SCOTLAND	No returns.	—
Totals for 1894	461,673	£1,171,366
„ „ previous year	438,998	£1,107,626

Quantity and Value of Roofing Slates exported from the United Kingdom in the years 1893 *and* 1894.

	1893		1894	
Countries to which Exported.	Quantities. Number.	Declared Value. £.	Quantities. Number.	Declared Value. £.
Norway	—	—	121,500	1,458
Denmark	2,411,800	29,158	2,852,700	34,211
Germany	30,922,700	141,743	33,465,100	174,951
Holland	308,500	1,012	10,000	27
Belgium	1,044,900	1,120	519,600	427
Channel Islands	523,700	4,243	570,600	4,481
France	1,009,300	1,436	933,400	2,223
Canary Islands	—	—	1,000	48

Countries to which Exported.	1893		1894	
	Quantities. Number.	Declared Value. £.	Quantities. Number.	Declared Value. £.
Austrian Territories	381,800	898	401,500	681
Roumania	—	—	10,500	91
Turkey	3,000	31	—	—
Egypt	7,200	49	—	—
West Coast of Africa	13,700	130	2,000	26
St. Helena	—	—	2,400	31
British Possessions in South Africa	500,500	4,101	445,300	3,578
British East Indies	93,700	816	84,600	568
Australasia	1,374,400	9,979	921,500	7,061
British West India Islands and Guiana	97,600	731	27,000	280
Foreign West Indies	25,300	150	22,700	135
Mexico	2,000	8	—	—
Chile	—	—	9,000	40
Brazil	19,000	124	3,600	53
Argentine Republic	—	—	55,000	443
Totals	38,739,100	£203,729	40,459,000	£230,813

Total production of the different Counties in England, Scotland, and Wales during the year 1886.

	Quantities in Tons.	Value at Mines or Quarries.
ENGLAND AND WALES—		
Breconshire	89	£112
Cardiganshire	155	349
Carnarvonshire	250,952	619,493
Cornwall	11,840	21,415
Cumberland	1,954	3,908
Denbighshire	3,016	4,603
Devonshire	1,070	1,055
Durham	1,469	1,005
Lancashire and Westmorland	3,355	6,509
Leicestershire	500	1,000
Merionethshire	144,034	408,181
Montgomeryshire	1,058	2,130
Somersetshire	1,000	2,000
Yorkshire	17,161	8,370
	437,653	£1,080,130
SCOTLAND—		
Argyllshire	17,355	24,689
Dumbartonshire	500	1,000
Perthshire	700	1,400
	18,555	£27,089
Totals for Great Britain for 1886	456,208	£1,107,169
Totals for 1885	468,954	£1,175,772

Quantities and Value of Slates exported from the United Kingdom during the years indicated.

Year.	Number.	Value.
1877	37,565,282	£294,515
1878	24,268,500	204,636
1879	27,801,100	183,915
1880	31,189,500	176,533
1881	38,415,100	212,699
1882	47,366,300	250,226
1883	34,544,400	192,257
1884	49,035,600	251,824
1885	45,482,000	242,484
1886	43,389,700	227,648
1893	38,739,100	203,729
1894	40,459,000	230,813

Quantities and Value of Roofing Slates exported from the United Kingdom in 1885 *and* 1886.

Countries to which sent.	1885		1886	
	Quantities. Number.	Declared Value. £.	Quantities. Number.	Declared Value. £.
Russia	—	—	9,500	83
Sweden	60,500	574	—	—
Norway	10,200	70	—	—
Denmark	2,442,300	27,888	1,846,000	19,497
Germany	31,279,100	148,952	31,828,700	155,962
Holland	307,100	913	301,000	1,004
Belgium	373,800	268	567,000	623
Channel Islands	595,700	4,139	532,800	3,764
France	1,571,500	3,291	790,000	1,113
Spain	—	—	7,300	49
Gibraltar	1,800	22	6,000	60
Austrian Territories	680,900	1,592	1,498,600	3,602
Turkey	4,000	75	—	—
West Coast of Africa	40,901	259	8,500	74
British Possessions in South Africa	291,500	1,646	197,200	1,067
British East Indies	69,900	596	6,000	43
Australasia	7,491,900	49,581	5,433,800	38,077
British North America	—	—	6,000	34
U.S. of America on the Atlantic	—	—	34,900	132
British West India Islands and Guiana	—	—	14,500	104
Foreign West Indies	5,000	44	—	—
Brazil	—	—	12,000	80
Uruguay	3,000	28	—	—
Argentine Republic	252,900	2,366	291,200	2,280
Totals	45,482,001	£242,484	43,389,700	£227,648

Spottiswoode & Co. Printers, New-street Square, London.

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